
## 2011 Annual Report of the

# Technology Innovation Program Advisory Board

NIST
National Institute of
Standards and Technology
U.S. Department of Commerce

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National Institute of Standards and Technology
Technology Innovation Program

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**Jeffrey P. Andrews,** (Chair)
SVP of Strategy and Business Development
Advanced Electron Beams
Wilmington, MA
*(Term expired 12/31/2011)*

**Dr. Vinton G. Cerf**
VP and Chief Internet Evangelist
Google, Inc.
Reston, VA
*(Term expire 12/31/2012)*

**Dr. Charles L. Cooney,**
Professor of Chemical Engineering
Massachusetts Institute of Technology
Cambridge, MA
*(Term expired 6/18/2011)*

**Dr. Martin Izzard**
Vice President
Texas Instruments
Dallas, TX
*(Term expired 6/18/2011)*

**Dr. Ray O. Johnson**
Senior Vice President and
Chief Technology Officer
Lockheed Martin Corporation
Bethesda, MD
*(Term expires 12/31/2012)*

**Dr. Radia Perlman**
Intel Laboratories
Redmond, WA
*(Term expired 12/31/2011)*

**Dr. Luis Proenza**
President
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Akron, OH
*(Term expires 6/18/2012)*

**James E. Reeb**
Director of Manufacturing R&D
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*(Term expires 6/11/2012)*

**Dr. William Peter Teagan**
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Acton, MA
*(Term expires 01/30/2013)*

# Introduction

The Technology Innovation Program (TIP) Advisory Board is a distinguished body of experts in the field of technology innovation, including representatives from high-tech companies, the venture capital community, and universities. The TIP Advisory Board was established by statute to advise the TIP Director on programs, plans and policies, including reporting on the general health of the program and its effectiveness in meeting its legislatively mandated mission, and offering guidance on investment areas appropriate for funding.[1] TIP promotes and accelerates innovation in the United States by offering competitive opportunities for cost-shared funding for high-risk, high-reward research that has the potential to yield transformational results.

TIP funds projects only in areas of critical national need. A critical national need is defined in the TIP Rule (15 C.F.R. Part 296) as "an area that justifies government attention because the magnitude of the problem is large, and the societal challenges that need to be overcome are not being addressed, but could be addressed through high-risk, high-reward research." A societal challenge is defined in the Rule as "a problem or issue confronted by society that when not addressed could negatively affect the overall function and quality of life of the nation, and as such justifies government attention, and can be addressed through high-risk, high-reward research." American competitiveness is an issue that has received considerable attention in recent years. The creation of TIP was a response to concerns about the need to foster technological innovation in the UnitedStates to help ensure future economic growth while simultaneously addressing critical national problems amenable to technological solutions.

Fiscal Year 2012 Congressional appropriations for the National Institute of Standards and Technology (NIST) include no funding for the Program. There is no reason to believe that new appropriations would be forthcoming in FY 2013 or beyond. Consequently, TIP is currently being phased out. Carry-over funding will allow many of the ongoing projects to be completed. In the case of projects for which insufficient funding is available to complete them, the recipients have been notified.

This annual report includes two calendar year 2011 TIP Advisory Board meetings:

- May 18
- December 6

During the Advisory Board meetings TIP and NIST staff briefed the Board on plans, recent events, and accomplishments. TIP's management raised special issues and concerns for which Board input was sought. TIP award recipients briefed the Board to provide examples of technical progress that has been made. The meetings included open-ended discussion sessions during which the Board provided feedback to TIP.

Following each meeting minutes were prepared, circulated to the Board members, and posted on the TIP website. Meetings of the TIP Advisory Board are open to the public.

This Advisory Board takes seriously its responsibility for guiding the course of the program. TIP staff members have welcomed advice from the Board and taken it into account as plans were developed and revised.

This report documents the Board's findings and recommendations and summarizes events that transpired at the two 2011 meetings. The appendices provide additional information about progress within the program, including a list of all projects funded to date, progress reports on projects, and a summary of white papers received by TIP regarding potential future investment areas.

[1] The TIP Advisory Board charter can be found on TIP's website (http://www.nist.gov/tip/adv_brd/index.cfm).

# Findings and Recommendations

## Findings

1. The Board was deeply saddened by the news that TIP will not be continued. As specified in its charter, TIP focuses on high-risk high-reward research to find technical solutions for critical national needs as determined by a rigorous review process based on input from industry and academia. Its mission was well crafted. In terms of fair and careful project selection, conscientious project management, important technical progress, thorough evaluation, and the delivery of value for the tax dollars spent, this program must be deemed a success. TIP is an excellent example of successful partnering between the federal government, industry, and universities. It was launched with bipartisan support. For all these reasons it is truly unfortunate that no funding could be found to continue the Program.
2. The Advisory Board has been pleased at how receptive the Program has been to advice from the Board. The Board members have enjoyed the opportunity to study this unusual program, and has been gratified that its advice has been taken seriously.
3. The Board commends TIP leadership for continuing to manage the program responsibly in spite of budgetary turmoil. Deputy Director, Dr. Lorel Wisniewski, and more recently, Deputy Director Dr. Robert Sienkiewicz, have maintained TIP staff morale and dedication at a high level through this difficult period.
4. The program did not suffer from a lack of meritorious proposals. About ten percent of the proposals submitted to TIP typically received funding, so TIP made awards only to the very best of the submissions. Opportunities for technical advancement in critical national needs areas such as civil infrastructure and manufacturing are legion, and that situation is likely to persist for the foreseeable future. Because the need for research in such areas will continue, it is important that TIP's operating procedures and lessons learned be documented and preserved. It is quite possible that at some future date, when the federal budget is not as challenged as it is today, the nation will conclude that it needs to initiate another TIP-like program. TIP can serve as a model of how to organize and operate such a program.
5. Throughout the years that TIP existed, its long-range planning was made more difficult by the high degree of uncertainty about the timing and levels of future funding. Continuing resolutions in lieu of actual appropriations are becoming the rule rather than the exception, and that situation creates challenges in managing any federal financial assistance program.
6. TIP benefitted from being housed at NIST. The technical expertise so in evidence throughout NIST is deep and wide ranging, and TIP was able to draw upon that expertise effectively. TIP also made good use of expertise in other federal agencies. For example, experts from the National Institutes of Health have been consulted regarding program ideas involving health-related biological and medical topics.
7. Not only does TIP select projects in a fair and conscientious manner, once projects are awarded, it manages those projects actively and terminates projects that do not appear likely to succeed. The Board is also pleased that TIP systematically gathers data to quantify the degree of success of projects and the benefits resulting from them.
8. TIP's white paper process provided a neutral forum in which competing companies, universities and others could share their thoughts about important technology trends and needs without fear of violating anti-trust laws. The availability of this forum would have been valuable to the science and engineering community even if no projects had been funded.

## Recommendations

1. During the phase-down period, it is essential that TIP document thoroughly its procedures and accomplishments. It is quite possible that a future Congress might wish to recreate TIP or a program similar to TIP, and the know-how gained during TIP's years of operation should not be lost.
2. TIP should make a concerted effort to publicize its accomplishments. The taxpayers received good value for the funds invested in this program and that fact should be made widely known.
3. In its white paper process, TIP identified important national needs that could be addressed by innovative R&D. TIP should publicize those findings to ensure that decision makers don't forget that these challenges still need attention.
4. If, at some future date, Congress should decide to recreate a program similar to TIP, it should be housed at NIST. NIST has a sterling reputation for scientific prowess as well as objectivity and integrity. In a climate in which examples increasingly can be found of political polarization of federal programs, NIST can be proud of its success in remaining apolitical, making all decisions based on rigorous science and sound management practices.
5. The quality of TIP staff has been high, and the Board urges NIST to do all that can be done to find other suitable positions at NIST or elsewhere in the federal government for TIP staff.
6. Private sector funds rarely go to the research end of the R&D spectrum. For that reason, government funding tends to be most successful when focused on research rather than the commercialization end of the spectrum. Future programs modeled on the TIP should reflect that point of view.
7. For a program such as TIP that funds multi-year projects, unless the budget grows, the program in out years can be highly constrained by previous year decisions. One option for future programs might be to structure them so that each project receives funding that decreases with time. Any future program modeled after TIP should consider that option.
8. During much of its existence TIP did not announce competitions until the appropriated funds were actually in-hand. While this certainly is the most fiscally prudent way to operate, it created difficulties for applicants. A well-crafted TIP proposal is time consuming to prepare. In recent years continuing resolutions have occurred more often than not. When TIP eventually received funds for a new competition, it often occurred well into the fiscal year. Even if a competition were announced immediately upon receipt of new funds, potential proposers could likely have been discouraged from applying because of the short time window. Should a TIP-like program ever be resurrected, it would be important to announce anticipated competitions with more lead time. Of course it would be necessary to accompany announcements with suitable caveats explaining that the intended competition would be held if and when funds actually arrived at NIST.
9. To maximize the potential for innovation, critical national need topics should be broad. It was appropriate for TIP to announce topics such as manufacturing and civil infrastructure. Should a future program be modeled after TIP, its topics should be equally broad.
10. TIP required proposers to show that they had left no stone unturned in seeking alternative funding. While the Board understands the rationale for such a policy, if enforced too strictly, it can discourage people from submitting ideas that deserve funding. Of course if funding is readily available for a project elsewhere, then TIP should not fund it. But, requiring proposers to spend time going from place to place seeking funding without success could be so time consuming if done conscientiously, that the proposer could lose the window of opportunity to foreign competition. Scientists and engineers should spend most of their time working on innovative ideas rather than pursuing funding. If an idea is technologically innovative, addresses a problem that is a genuine national need, and is not being adequately supported, then the Federal government should be able to justify cost-shared support for it even though there might possibly be additional funds available somewhere. If the proposed work really does address a critical national need, then having more than one source provide funding may be entirely appropriate, and in some cases, desirable.
11. Any future program patterned after TIP should also have an advisory board consisting of experts similar to those who served on this board.

# Summary of Advisory Board Meetings Held in 2011

The full minutes of these meetings are posted on the TIP website (www.nist.gov/tip). Accordingly, only the most important points are summarized here.

## May 18 Meeting

### Introduction

Mr. Jeffrey Andrews, TIP Advisory Board Chair, called the meeting to order and introduced TIP Acting Director, Dr. Lorel Wisniewski, who in turn, introduced Dr. Phillip Singerman, NIST's Associate Director for Innovation and Industry Services. Under the NIST reorganization that took place in October 2010, NIST no longer has a Deputy Director, but instead, three Associate Directors. Dr. Singerman is responsible for NIST's extramural programs—the Technology Innovation Program, the Hollings Manufacturing Extension Partnership, and the Baldrige Performance Excellence Program, as well as the Economic Analysis Office, and the Office of Technology Partnerships.

Dr. Singerman thanked the Board members for their service and their good advice, and also thanked the highly dedicated TIP staff. He holds TIP in high regard, calling it "the gold standard for federal technology programs" because of its rigorous and thorough reviews of proposals and its value-added project management.

### Dr. Lorel Wisniewski - TIP Program and Budget Update

Dr. Wisniewski reviewed the new NIST organization chart and noted that NIST Director Dr. Patrick Gallagher now also serves as Commerce Undersecretary for Standards and Technology, thus giving NIST higher visibility within the Administration. While the reorganization has not changed TIP's internal management structure, it has tended to increase collaboration among the various parts of NIST.

Nine new TIP awards were announced in December 2010. Dr. Wisniewski reported that no funds were appropriated in FY 2011 for a new TIP competition, so staff effort has been focused on managing the thirty-eight ongoing TIP projects, as well as the remaining projects begun under a previous program—the Advanced Technology Program.

During the first years of TIP, competitions were announced only when funding actually became available. Proposals were typically due 90 days after the announcement of the competition. That short time window put pressure on applicants preparing proposals. Accordingly, the Board recommended that TIP publicize topical areas under consideration (with appropriate caveats that future competitions are subject to the appropriation of funding) so that potential proposers would have more lead time to plan proposals. Responding to this recommendation, TIP published a Program Plan in January. It indicated that if and when funding becomes available, TIP would run competitions in areas of critical national need such as manufacturing, energy, healthcare, and water.

Dr. Wisniewski's charts cited data on the projects in the two areas currently funded: Civil Infrastructure and Manufacturing. The ongoing projects involve $135.7 million in federal funding as well as awardee cost sharing, for a total investment of $279.7 million. One hundred thirty-two organizations participate in these projects. None has reached completion as yet.

The Board had urged TIP to define topical areas as broadly as possible. In response, the scope of the manufacturing topic was broadened to include biomanufacturing. The Board noted that in many industries, energy efficiency greatly impacts manufacturing.

### Civil Infrastructure: A Critical National Need

Mr. David Swanson of TIP presented an overview of the civil infrastructure topical area, and Dr. Felix Wu described representative examples of ongoing projects.

The two major aspects of civil infrastructure technology addressed by this topic are:

- Sensing and monitoring the degree of deterioration of existing infrastructure (e.g., bridges and highways), to improve strategic maintenance decision making.
- Developing repair and retrofit technologies for existing infrastructure.

In 2008 and 2009 TIP made seventeen awards in civil infrastructure, involving sixty-nine different organizations. TIP will provide $72.6 million, and the total investment is $149.9 million.

TIP organized five special sessions at the 2011 meeting of the Society of Photo-Optical Instrumentation Engineers. At this event, forty-seven papers were presented by TIP awardees. Attendees agreed that there is value in sharing findings in this type of forum.

Three examples of ongoing civil infrastructure projects were described in some detail at this Advisory Board meeting:

Project 1: This joint venture project goes by the acronym "VOTERS" ("Versatile Onboard Traffic Embedded Roaming Sensors"). The project involves three universities plus instrumentation firms. By instrumenting a vehicle with a family of suitably designed instrumentation systems (including ground penetrating radar, acoustic and vibration sensors, optical profilometry, and millimeter wave radar), the vehicle can travel a roadway at traffic speeds while collecting data on the condition of the roadway.

Project 2: "Cyber-enabled Wireless Monitoring Systems for the Protection of Deteriorating National Infrastructure Systems." This is a large joint venture involving the University of Michigan plus several instrumentation and modeling firms. For quite some time structural engineers have envisioned equipping bridges or other critical structures with sensors to provide ongoing data on structural integrity. While this can be done in principle, and experiments have been carried out with existing technology, it has not proven practical for widespread application. A major problem is that on a large structure, this approach requires a significant number of sensors, and if the sensors are battery powered, the batteries must be replaced much too frequently for the approach to be cost effective. Connecting a large number of sensors with wires from a power supply is also expensive. Ideally one would like to be able to utilize a large number of low-cost easy to attach sensors to existing structures, each of which could be interrogated wirelessly.

In this project, the researchers are investigating self-sensing cement-based materials and sensors powered by "harvested" power, that is, power from renewable sources such as tiny wind turbines. The other innovation is to employ a wireless network involving sensor nodes operating at two orders of magnitude lower power than existing technology.

Project 3: "Next Generation SCADA for Prevention and Mitigation of Water System Infrastructure Disaster." This project investigates non-invasive monitoring technology for failures in drinking water and waste water collection systems. The project involves the University of California at Irvine, and also involves private sector participation and several municipal water and sanitation districts. The idea is to instrument a piping network with a sufficient number of sensors and monitor them so that should a leak or rupture occur, the infrastructural manager can determine immediately how serious the problem is and where it has occurred. Field testing is underway.

Establishing baseline data is important. If the "signature" of a bridge is determined when it is new, and a model exists of how that bridge is expected to behave under stress, then changes to that baseline over time can be important. The challenge is to understand what particular vibration signature correlates with impending bridge failure, and whether the data collected are sufficiently meaningful to be actionable.

Wireless technology has many advantages over wired systems. The proliferation of wire cables and multiple channels can be costly. The new Interstate highway bridge in Minneapolis to replace the one that collapsed has a network of 323 embedded wired sensors, but current technology for performing this task is cumbersome and expensive.

TIP invited two TIP awardees to address the Board to share their experiences carrying out TIP-sponsored research. Dr. Mohammed Ettouney of Weidlinger Associates spoke first about his work.

## Dr. Mohammed Ettouney

Dr. Ettouney noted that within the next fifteen years, fifty percent of the nation's more than 600,000 bridges will be more than fifty years old. Thus the urgency of the kind of research described at this meeting should be obvious. Federal, state, and local governments are all in a period of unprecedented austerity; hence aging bridges cannot be replaced unless the need is acute. Pre-stressed concrete bridges are a particular challenge because the internal deterioration is not visible. Better data for decision making is needed. Structural health monitoring has been around for a long time, but the nature of this TIP project is more innovative than any he had been involved in previously.

Structural health monitoring systems are not widely used today for a variety of reasons: today's sensors do not measure damage directly; point sensors detect conditions at one particular point rather than over a wider area; wired sensors are expensive and difficult to install on large structures; and managing and interpreting large volumes of data is a challenge. All of this is of no use unless it helps the structure operator make tough decisions. (Does this bridge need to be shut down?)

Dr. Ettouney considers this project to be a potentially paradigm-shifting effort with major impact. He applauded TIP for funding projects of this kind. Dr. Ettouney feels that the interdisciplinary teaming of university civil and electrical engineers, and material and computer scientists, plus industry experts from equipment manufacturers and also state transportation departments is unique and valuable. For project success, all of the elements must be compatible and developed in parallel, and TIP enables that.

Measurements include stress, strain, acceleration, etc. The challenge is to weave all those data into a degradation model capable of meaningful prediction.

Rebar degradation in pre-stressed concrete bridges cannot be observed visually. People have used X-rays to assess damage, but that does not lend itself to *continuous* monitoring. Some of the work revolves around establishing a baseline and then seeing how things shift with time as the bridge ages. Modeling behavior is important. Deflections should be within a certain range, and if they exceed the design range, that can be a warning that something is wrong. Users want simple unambiguous answers such as "Is this bridge about to fail or not?" Giving a simple "yes" or "no" to such questions is difficult.

## Professor Daniel Inman

Professor Daniel Inman of Virginia Tech was the second presenter (Dr. Inman was out of the country but participated remotely via the Internet). The goal of this project is to lower the power requirements of sensing systems and raise the power output of power harvesting devices so that structural monitoring systems can eliminate batteries.

Dr. Inman's expertise is in tiny highly efficient wind turbines. At present he can create mini wind turbines (for wind speeds down to 1-2 mph) capable of generating about fifty milliwatts or more, but the hope is that future progress might raise that number to something near a watt.

He emphasized the unique nature of TIP funding. National Science Foundation (NSF) funding is different. NSF supports open ended basic research, whereas TIP projects strive to produce actual hardware to demonstrate the feasibility of new technology. TIP projects have milestones and quantified objectives to be met. The fact that TIP can fund projects for up to five years is important for university participation since that is the time that a PhD grad student typically requires. TIP encourages teaming between universities and industry, which means that grad students get a taste of what life in industry is like. He also considers it appropriate that TIP asks participants to agree on intellectual property rights before beginning work.

Fifty milliwatts of output (from a wind turbine) has been achieved. One hundred mW is the goal for 2011. A successful demonstration took place in February. The basic feasibility of harvested energy for this application has been demonstrated. Batteries for this application tend to wear out. Reliability in this kind of application is certainly important. Lifetimes need to be many years in under difficult ambient conditions.

## Manufacturing—a Critical National Need

TIP staff members Dr. Michael Schen, Dr. Jean-Louis Staudenmann, and Dr. Donald Archer were the presenters for this agenda item.

Dr. Schen began by pointing out that when NIST's predecessor, the National Bureau of Standards, was created by Congress in 1901; aid to U.S. manufacturers was an explicit part of the charter, so TIP's current efforts to improve manufacturing are fully consistent with a long-standing NIST/NBS mission element. The NIST laboratories have many scientists and engineers with expertise in various aspect of manufacturing, and TIP is able to draw upon their knowledge to supplement TIP expertise.

While a significant amount of U.S. manufacturing has moved offshore in the past few decades, the United States is still the world's largest manufacturing economy (followed by China and Japan). To reap the benefits of new technological breakthroughs, those breakthroughs must be transitioned into products that can be manufactured. Thus innovation and manufacturing are closely linked. Economic growth is stimulated by new technology and the ability to manufacture innovative products incorporating that new technology. Industry and universities see numerous opportunities for improving U.S. manufacturing prowess. That led to the justification for naming manufacturing a critical national need.

In 2009 and 2010 TIP encouraged applicants interested in manufacturing research to submit proposals dealing with accelerating the availability of advanced materials and their incorporation into new products. In 2010 the scope was broadened considerably to include critical process advances. Biomanufacturing has also been added to the scope. The twenty-one manufacturing research projects funded to date total $129.8 million, of which

$63.1 million is the federal share.

Examples of ongoing projects were described by the speakers, e.g.,

- Silicon nanowires for lithium-ion batteries
- Scale-up for manufacturing nanocomposites with sub-10 nm particles
- Magnesium diboride superconductors
- Nanographene
- Semiconducting single-walled carbon nano tube inks
- Sensors for recycling high-value aerospace materials

Today, lighter and stronger structures such as bridges can be built with high strength steels and other advanced materials. Nanotechnology is important because materials with smaller grain size generally are stronger. A variety of new techniques for creating nanostructured materials are being explored. Much promising work has been done with nanoparticles in laboratory settings, but scaling up to industrial scale processes presents many new challenges. Conventional molding techniques may not work for these advanced materials, and that is another area where research is needed.

In addition to pursuing opportunities for creating improved metal alloys, TIP is funding a project involving engineered cementatious composites. If that project is successful, it might lead to high-strength concrete that could be bent like a metal without breaking.

In describing the TIP-funded recycling project, it was noted that in the future, as exotic materials become increasingly rare, it could be necessary to "mine" landfills. Even for common materials, the time may come when that could be necessary. It has been estimated that one third of the world's copper is in use, one third is still in mines, and the remaining third is in landfills. When the cost of obtaining copper from mines becomes sufficiently high, recycling from landfills could be become a viable option. Many exotic alloys must be exceedingly pure to preserve their properties, hence the ability to detect traces of unwanted contaminants in a recycle process stream will become increasingly important, and TIP-funded researchers are exploring that area. In one application cited, it is necessary to achieve 99.9999 percent sorting accuracy, and do it at an affordable cost.

Biomanufacturing is another important field in which TIP funding is leading to new manufacturing technology. TIP consulted with and solicited input from the National Institute of Biomedical Imaging and Bioengineering within the National Institutes of Health in developing this program area.

The cost of manufacturing biopharamaceuticals is a driver of increasing medical costs. While there is intense debate among politicians about the government's role in dealing with rising healthcare costs, there is no disagreement that new lower cost manufacturing methods for biopharmaceutical products would be beneficial to the nation. Given the complexity of the processes typically used to make biopharmaceuticals, high-risk research is needed if there is any hope of achieving significant cost reductions, and TIP funded research is providing encouraging results. One TIP project has the potential for reducing by 80 percent the cost of producing therapeutic proteins.

Examples of biomanufacturing projects include:

- Genetic engineering for real time process monitoring of therapeutic proteins
- New tools to improve the therapeutic action of manufactured proteins
- Freeze dry processes for powder forms for biomolecules
- Gene transfer vehicles for vaccination, gene therapy, and tissue transplantation
- Hollow drug-filled fibers for drug delivery and tissue engineering

The beneficial applications of these techniques are many and worth pursuing. Some of these TIP projects could lead to ways of making stockpiles of antidotes and vaccines for bioterrorism attacks at more affordable costs, and that is clearly an important aspect of defense. TIP focuses on high volume production and quality control issues, not small batches.

## Discussion of Board Recommendations

TIP has strived to address Board recommendations noted in previous Board minutes and reports.

With regard to communicating with the public:

- A five-year TIP plan has been developed and publicized
- Outreach has been stepped up, including webinars
- Project showcases are being planned
- TIP and public white papers are on the web, with electronic comments solicited
- TIP and NIST's Manufacturing Extension Partnership (MEP) are collaborating

With regard to operational improvements:

- The five-year plan has been developed and publicized
- The scope of the manufacturing area was broadened
- An analysis was made of where proposers had the most difficulty so that more assistance and advice can be provided in the future
- Terminated projects from the Advanced Technology Program were studied to see how lessons learned there might help avoid failures in TIP projects.

TIP continues to build its network of collaboration with other federal and state technology agencies.

The Board noted its ongoing concern about the requirement that proposers must show that they "have left no stone unturned" in seeking funding elsewhere. If rigorously enforced, that could be a deterrent to apply, even for projects that are clearly important to the nation and deserving of support. TIP staff noted that it is common for TIP proposals to fail to address that criterion adequately. It does seem appropriate to expect applicants to provide evidence that federal funding is really needed for a particular project to go forward.

While it is reasonable to ask TIP applicants to explain why the private sector is unlikely to provide all the funding for a project, it is too demanding to expect them to *prove* that no private funding is available. In the time that it would take to prove that no private funding is available (by diligently going to many potential sources and being turned down repeatedly, the window of opportunity for the new technology could be lost to foreign competition.

If an applicant's project has potential for high profits, and the time frame is short, the venture capital community will probably fund it, but there are many projects that are of great potential value to society, where the time frame is longer, and where the potential for high profits is less. Those are the kinds of projects where TIP funding makes sense.

TIP has suspended projects until specific issues were resolved, but no projects have been terminated as yet. TIP reserves the right to do so if the project gets off track. Historically, about ten percent of projects were terminated under the former Advanced Technology Program (ATP). A variety of circumstances led to the terminations, such as, the company was purchased by a new owner that had other business or research priorities, or the technology development turned out to be much more difficult than envisioned. Many of the terminations were at the request of the recipient and not necessarily for non-compliance issues.

TIP proposers contribute their indirect costs as cost share and may be able to get a contribution to cost sharing funds from other sources. Sometimes a state technology agency will agree that if TIP funds are awarded, the state agency will provide a grant to cover some of the cost share. Of course, universities are in a different situation than, say, small start-up companies. Companies are willing to risk substantial blocks of their own resources because they hope to create a new technology that will pay dividends down the road. Indirect costs as cost share typically make up the majority of the TIP cost share requirement.

In the Advanced Technology Program, a predecessor of TIP, business plans were considered along with technical plans. Retired business executives and people with prior venture capital experience were recruited to review the business plans. TIP requires information regarding the potential for impacts from the project, but does not require submission of business plans; instead the emphasis is on the technical plans. If current private sector people were involved in the TIP selection process, reviewing proposals in their areas of expertise, there would be the potential for conflict of interest issues and issues related to protection of company proprietary information. TIP must ensure that proprietary information is protected and does not inadvertently fall into the hands of competitors.

## December 6 Meeting

### Introduction

This meeting was conducted via a webinar open to the public.

Advisory Board Chair, Mr. Jeffrey Andrews, welcomed the attendees and called the meeting to order. Dr. Phillip Singerman, NIST's Associate Director for Innovation and Industry Services, thanked the Advisory Board members for their service and explained that no funding has been appropriated for TIP in Fiscal Year 2012. He explained that the Program is being shut down. There is sufficient previously obligated carry-over funding to complete most, but not all, of the ongoing projects (details to follow).

Approximately forty-five TIP staff members will lose their jobs ultimately. Of those, eleven have already secured other employment. However, it will be necessary to continue to monitor and manage the ongoing projects, so a small staff will remain for approximately two years until all projects are completed by the end of April 2014.

Dr. Singerman expressed his personal opinion that TIP, as well as the Advanced Technology Program that preceded it, were deserving of praise. Both received accolades from many quarters because of the rigor with which they had been managed. The subject of numerous outside studies, these two programs had become international models for successful public/private partnerships to foster new technology and cutting edge research.

### Plans for Program Phase Out

During this shut-down period it will be important to document the procedures and the impact of the program. It is conceivable that at some future date when the economy recovers and interest in government-industry-university partnerships resumes, policymakers might wish to resurrect a program with some or all of the features of TIP. Careful documentation, therefore, is a priority.

The Board expressed puzzlement that the TIP, which, by all indications, was successful in carrying out its important mission (a mission that addresses critical national needs), did not receive funding in Fiscal Year 2012. Several other agencies have programs similar to TIP that are not being terminated. While NIST's mission clearly includes supporting U.S. industry, it may be that NIST is not widely recognized as having this mission element, and therefore, some may question whether TIP is an essential part of NIST's mission. In the 1990s the Advanced Technology Program, TIP's predecessor, generated political controversy, and some of that controversy may have rubbed off on TIP, even though TIP is a different program in many respects and was launched with bipartisan support.

Dr. Sienkiewicz provided more details on the program phase-out plan. He also thanked the Advisory Board members for the helpful advice they had provided to the program since its inception. He feels that TIP has accomplished much during its brief tenure.

Forty-eight active projects remain, and by the end of 2012 there will be approximately forty. Most have been fully funded with previously obligated funds. Twelve projects will be ended earlier than planned due to lack of continued funding to meet the originally requested funding level and those recipients have been notified.

TIP's staff is being downsized, but there will be a need to keep a few project managers available until all projects end. Each project manager is expected to monitor eight or ten projects. NIST has a fiduciary responsibility to ensure that all projects are monitored and managed appropriately. TIP staff has already been reduced to thirty-four people. By the end of Fiscal Year 2012, the number of remaining staff will be only five or six. Approximately 23 projects will remain by May 2013. By the third quarter of FY 2013 only about three TIP people will remain to close out the remaining 22 projects. All projects will end by the end of November 2014

NIST is helping TIP staff find new jobs. Some will take early retirement, but there may have to be a formal RIF (reduction in force) action. Steps are being taken to reduce costs such as limiting travel to essential project management travel, and reviewing current TIP contracts for goods and services. For example, TIP will no longer need various contracts for information technology systems support.

TIP is required to identify key files that need to be retained and archive them in a responsible manner. Dr. Sienkiewicz commented that TIP has an obligation to taxpayers to document accomplishments and lessons learned. Success stories will be captured and limited case studies done on TIP projects.

Dr. Sienkiewicz spoke with pride in summarizing the accomplishments of TIP and ATP. It has been said that ATP created a whole new industry—the DNA diagnostics industry. TIP-funded civil infrastructure R&D work has already resulted in important new

tools for industry and government. The collaboration between industry, government, and universities in both ATP and TIP has been impressive, and often continues beyond the duration of individual projects. Both ATP and TIP have funded predominately small businesses—in many cases, very small high tech companies.

Both ATP and TIP have been models of rigorous and fair project selection with extensive peer review. Conscientious project management and project evaluation have been watchwords. The National Academies have praised the methodology that NIST has used in operating these extramural programs.

## Comments from the Board

The board believes that TIP has been a very well-run, tightly managed program. TIP has done an outstanding job performing case studies.

For a program such as TIP that funds multi-year projects, unless the budget grows, the program in out years can be highly constrained by previous year decisions. One option for future programs might be to structure them so that each project receives funding that decreases with time. The National Science Foundation did this with network access projects, structuring them so that they had to become self-supporting ultimately.

The Department of Energy has also used a similar approach for some programs by increasing recipient cost share over the life of a project.

Private sector funds rarely go to the research end of the R&D spectrum. For that reason, government funding tends to be most successful when focused on research rather than the commercialization end of the spectrum.

# Appendix 1
# TIP Projects Funded to Date

## TIP Project Awards, FY2010 Competitive Funding Opportunity

### Critical National Need: Manufacturing

***"Manufacturing and Biomanufacturing: Materials Advances and Critical Processes"***

**Manufacturing of Fully Deleted Helper-Virus Independent Adenoviral Vectors**
Isogenis, Inc. (Aurora, Colo.)

Project Duration**:** 3 years
Projected TIP Contribution: $2.7 M
Total Project Cost (est.): $5.5 M

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**Volume Production of Nanocomposite Alloy Anode Materials for Lithium-Ion Batteries**
ActaCell, Inc. (Austin, Texas)

Project Duration: 3 years
Projected TIP Contribution: $3 M
Total Project Cost (est.): $6.2 M

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**Atmospheric Spray Freeze-Dried Powder Process Advancement and Scale-Up**
Engineered BioPharmaceuticals, Inc. (Manchester, Conn.)

Project Duration: 3 years
Projected TIP Contribution: $3 M
Total Project Cost (est.): $6 M

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**High-Throughput Manufacturing of Electrospun Core-Sheath Fibers**
Arsenal Medical, Inc. (Watertown, Mass.)

Project Duration: 3 years
Projected TIP Contribution: $2.3 M
Total Project Cost (est.): $4.7 M

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**Process Innovation for High Technology Manufacturing of Flexible Liquid Crystal Displays**
Kent Displays, Inc. (Kent, Ohio)

Project Duration: 3 years
Projected TIP Contribution: $3 M
Total Project Cost (est.): $6 M

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**Reprogram a Mammalian Cell Line to Optimize Production of Biopharmaceuticals**
Precision BioSciences, Inc. (Research Triangle Park, N.C.)

Project Duration: 3 years
Projected TIP Contribution: $2.7 M
Total Project Cost (est.): $5.4 M

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**Volatile Reporters for Monitoring Biomanufacturing of Therapeutic Proteins**
Ginkgo BioWorks (Boston, Mass.)

Project Duration: 2 years
Projected TIP Contribution: $1 M
Total Project Cost (est.): $2.3 M

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**Low-Cost, Scalable Manufacturing of Surface-Engineered Super-Hard Substrates for Next-Generation Electronic and Photonic Devices**
Sinmat Inc. (Gainesville, Fla.)

Project Duration: 3 years
Projected TIP Contribution: $2.4 M
Total Project Cost (est.): $4.8 M

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**Synthesis of High-Efficiency Organic Photovoltaics for Scalable, Cost-Effective Manufacturing**
Polyera Corporation (Skokie, Ill.)

Project Duration: 2 years
Projected TIP Contribution: $2 M
Total Project Cost (est.): $5 M

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# TIP Project Awards, FY 2009 Competitive Funding Opportunity

## Critical National Need: Manufacturing

***"Accelerating the Incorporation of Materials Advances into Manufacturing Processes"***

**Production of Low-Cost, High-Quality Metallic and Semiconducting Single-Walled Carbon Nanotube Inks**
Brewer Science, Inc. (Rolla, MO), joint venture lead, with SouthWest NanoTechnologies (SWeNT), Norman, OK)

Project Duration: 3 years
Projected TIP Contribution: $6,527,000
Total Project Cost (est.): $13,910,000

**Functionalized Nanographene for Next-Generation Nano-Enhanced Products**
Angstron Materials, LLC (Dayton, OH)

Project Duration: 3 years
Projected TIP Contribution: $1,494,000
Total Project Cost (est.): $2,988,000

**Transformational Casting Technology for Fabrication of Ultra-High-Performance Lightweight Aluminum and Magnesium Nanocomposites**
University of Wisconsin-Madison (Madison, WI), joint venture lead; with Eck Industries, Inc. (Manitowoc, WI), Nanostructured & Amorphous Materials, Inc. (Houston, TX), the Oshkosh Corporation (Oshkosh, WI), and Wisconsin Alumni Research Foundation (Madison, WI)

Project Duration: 5 years
Projected TIP Contribution: $4,863,000
Total Project Cost (est.): $10,092,000

**High-Speed, Continuous Manufacturing of Nano-Doped Magnesium Diboride Superconductors for Next-Generation MRI Systems**
Hyper Tech Research, Inc. (Columbus, OH)

Project Duration: 3 years
Projected TIP Contribution: $3,000,000
Total Project Cost (est.): $6,050,000

**PRINT® Nanomanufacturing: Enabling Rationally Designed Nanoparticles for Next-Generation Therapeutics**
Liquidia Technologies, Inc. (Durham, NC)

Project Duration: 3 years
Projected TIP Contribution: $2,971,000
Total Project Cost (est.): $5,942,000

**Silicon Nanowire Production for Advanced Lithium-Ion Batteries**
Amprius, Inc. (Menlo Park, CA)

Project Duration: 2 years
Projected TIP Contribution: $3,000,000
Total Project Cost (est.): $6,000,000

**Integrated Multiscale Modeling for Development of Machinable Advanced Alloys and Corresponding Component Machining Processes**
Third Wave Systems, Inc. (Minneapolis, MN)

Project Duration: 3 years
Projected TIP Contribution: $1,564,000
Total Project Cost (est.): $3,170,000

**High-Volume Production of Nanocomposite Electrode Materials for Lithium-Ion Batteries**
A123Systems, Inc. (Ann Arbor, MI)

Project Duration: 3 years
Projected TIP Contribution: $2,864,000
Total Project Cost (est.): $6,000,000

**Building U.S. Strategic Metals Competitiveness through Integration of Advanced Sensor Technologies**
wTe Corporation (Bedford, MA), joint venture lead, with National Recovery Technologies, Inc. (Staten Island, NY) and Energy Research Co. (Nashville, TN)

Project Duration: 4 years
Projected TIP Contribution: $5,670,000
Total Project Cost (est.): $11,532,000

**Homogeneous Three-Dimensional Pultruded Processing of PEEK, PEI, and PPS High-Temperature Thermoplastic Composite Profiles**
Ebert Composites Corporation (Chula Vista, CA)

Project Duration: 2 years
Projected TIP Contribution: $1,866,000
Total Project Cost (est.): $4,018,000

**High-Risk, Low-Cost Carbon Nanofiber Manufacturing Process Scale-Up**
Spin Technologies, Inc. (Chattanooga, TN)

Project Duration: 3 years
Total project (est.): $6,006,000
Requested TIP funds: $3,000,000

**Development and Scale-Up of Nanocomposites with Sub-10 nanometerParticles**
Pixelligent Technologies LLC (College Park, MD), joint venture lead, with Brewer Science, Inc. (Rolla, MO)

Project Duration: 3 years
Projected TIP contribution: $4,089,000
Total project cost (est.): $8,178,000

## Critical National Need: Civil Infrastructure

***"Advanced Sensing Technologies and Advanced Repair Materials for the Infrastructure: Water Systems, Dams, Levees, Bridges, Roads, and Highways"***

**Civil Infrastructure Inspection and Monitoring Using Unmanned Air Vehicles**
The Droid Works, Inc. (Framingham, MA), with the Georgia Institute of Technology Research Corporation

Project Duration: 3 years
Projected TIP Contribution: $2,453,000
Total Project Cost (est.): $4,996,000

**Automated Nondestructive Evaluation and Rehabilitation System (ANDERS) for Bridge Decks**
Rutgers, The State University of New Jersey (Piscataway, NJ), joint venture lead, with Drexel University (Philadelphia, PA), PD-LD, Inc. (Pennington, NJ), Mala GeoSciences USA, Inc. (Charleston, SC), and Pennoni Associates, Inc. (Philadelphia, PA).

Project Duration: 5 years
Projected TIP Contribution: $8,810,000
Total Project Cost (est.): $17,923,000

**Distributed Fiber-Optic Sensing Technology for Civil Infrastructure Management**
Optellios, Inc. (Newtown, PA)

Project Duration: 3 years
Projected TIP Contribution: $1,930,000
Total Project Cost (est.): $3,917,000

**Robotic Rehabilitation of Aging Water Pipelines**
FibrwrapConstruction, Inc. (Ontario, CA; joint venture lead, with Fyfe Company (San Diego, CA) and the University of California, Irvine

Project Duration: 5 years
Projected TIP Contribution: $8,462,000
Total Project Cost (est.): $17,582,000

**A Rapid Underground Pipe Rehabilitation Technology**
LMK Enterprises, Inc. (Ottawa, IL)

Project Duration: 2 years
Projected TIP Contribution: $1,701,000
Total Project Cost (est.): $3,411,000

**Development of a Multiscale Monitoring and Health Assessment Framework for Effective Management of Levees and Flood-Control Infrastructure Systems**
Rensselaer Polytechnic Institute (Troy, NY), joint venture lead, with Geocomp Corporation (Boxborough, MA)

Project Duration: 4 years
Projected TIP Contribution: $3,462,000
Total Project Cost (est.): $6,928,000

**Development of High-Toughness, Low-Viscosity Resin for Reinforcing Pothole Patching Materials**
University of California, Los Angeles, joint venture lead, with Materia, Inc. (Pasadena, CA)

Project Duration: 3 years
Projected TIP Contribution: $1,499,000
Total project cost (est.): $3,051,000

**Advanced Coating Technology for Infrastructure;**
MesoCoat, Inc. (Euclid, OH), joint venture lead, with The Edison Materials Technology Center (Dayton, OH) and Polythermics, LLC (Kirkland, WA)

Project Duration: 3 years
Projected TIP Contribution: $1,792,000
Total project cost (est.): $3,956,000

# TIP Project Awards, FY 2008 Competitive Funding Opportunity

## Critical National Need: Civil Infrastructure

***"Advanced Sensing Technologies for the Infrastructure: Roads, Highways, Bridges and Water Systems"***

**Development of SCANSn for Advanced Health Management of Civil Infrastructures**
Acellent Technologies, Inc. (Sunnyvale, CA)

Project duration: 3 years
Projected TIP contribution: $2,995,000
Project cost-share contribution: $2,995,000

**Fiber Sensing System for Civil Infrastructure Health Monitoring**
Distributed Sensor Technologies, Inc. (Santa Clara, Calif., joint venture lead, with Optiphase, Inc., (Van Nuys, CA), Redfern Integrated Optics, Inc., (Santa Clara, CA) and the University of Illinois at Chicago

Project duration: 3 years
Projected TIP contribution: $4,030,000
Project cost-share contribution: $4,518,000

**Infrastructure Defect Recognition, Visualization and Failure Prediction System Utilizing Ultrawideband Pulse Radar Profilometry**
ELXSI Corporation (Orlando, FL), joint venture lead, with UltraScan, LLC. (Ruston, LA) and Louisiana Tech University (Ruston, LA)

Project duration: 3 years
Projected TIP contribution: $3,119,000
Project cost-share contribution: $3,629,000

**Microwave Thermoelectric Imager for Corrosion Detection and Monitoring in Reinforced Concrete**
Newport Sensors, Inc. (Irvine, CA)

Project duration: 3 years
Projected TIP contribution: $1,249,000
Project cost-share contribution: $1,249,000

**VOTERS: Versatile Onboard Traffic Embedded Roaming Sensors**
Northeastern University (Boston, MA), joint venture lead, with the University of Massachusetts at Lowell, the University of Vermont and State Agricultural College (Burlington, VT) and Witten Technologies, Inc., (Somerville, MA)

Project duration: 5 years
Projected TIP contribution: $9,000,000
Project cost-share contribution: $9,802,000

**Self-Powered Wireless Sensor Network for Structural Bridge Health Prognosis**
Physical Acoustics Corporation (Princeton Junction, NJ), joint venture lead, with Virginia Tech (Blacksburg, VA), the University of South Carolina (Columbia, SC) and the University of Miami (Coral Gables, FL)

Project duration: 5 years
Projected TIP contribution: $6,930,000
Project cost-share contribution: $6,969,000

**Next Generation SCADA for Prevention and Mitigation of Water System Infrastructure Disaster**
University of California at Irvine (Irvine, CA), joint venture lead, with Earth Mechanics, Inc. (Fountain Valley, CA), the Irvine Ranch Water District (Irvine, CA), the Orange County Sanitation District (Fountain Valley, CA), and the Santa Ana Watershed Project Authority (Riverside, CA)

Project duration: 3 years
Projected TIP contribution: $2,800,000
Project cost-share contribution: $2,885,000

**Cyber-Enabled Wireless Monitoring Systems for the Protection of Deteriorating National Infrastructure Systems**
University of Michigan (Ann Arbor, MI), joint venture lead, with Weidlinger Associates (New York, NY), SC Solutions (Santa Clara, CA), LFL Associates (Ann Arbor, MI), Monarch Antenna (Ann Arbor, MI), and Prospect Solutions (Albany, NY)

Project duration: 5 years
Projected TIP contribution: $8,998,000
Project cost-share contribution: $10,164,000

**Development of Rapid, Reliable, and Economic Methods for Inspection and Monitoring of Highway Bridges**
The University of Texas at Austin (Austin, TX), joint venture lead, with National Instruments Corporation (Austin, TX) and Wiss, Janney, Elstner Associates, Inc., (Northbrook, IL)

Project duration: 5 years
Projected TIP contribution: $3,421,000
Project cost-share contribution: $3,421,000

# Appendix 2
# TIP Engagement with the S&T Community

## 1) Summary of White Papers Submitted to TIP

On October 29, 2010, TIP renewed its call to solicit white papers from the public.[2] In this call for white papers, TIP is seeking information in all areas of critical national need, including information to assist TIP in further defining several areas of interest for future TIP funding opportunities, and also to identify new areas for consideration. By September 30, 2011, TIP received white papers as follows:

Total number of white papers received: ..... 276

Number of authors and contributors: ..... 590

Organizational affiliation of author/contributor: ..... 355

- University ..... 193
- Small/medium company ..... 254
- Large company ..... 36
- Non-profit organization ..... 54
- Government/national laboratory ..... 19
- Foreign entity ..... 16
- Individual/no organizational affiliation ..... 18

Number of states represented: ..... 43[3]

The technologies discussed in the submitted white papers are often cross-disciplinary. A categorization of the technologies by major topic area follows:

- Civil Infrastructure ..... 21
- Complex Systems and Networks ..... 17
- Electronics/Photonics ..... 22
- Energy ..... 79
- Green technology [sustainability] ..... 14
- Healthcare ..... 44
- Manufacturing ..... 68
- Security ..... 24
- Water ..... 11
- Other ..... 19[4]

[2] *Federal Register*, 75, no. 209, Friday, October 29, 2009, p. 66739. TIP issued its first call for white papers on December 16, 2008.

[3] The District of Columbia was also represented.

[4] "Other" includes aircraft, agriculture, aquaculture, software development, education and social science.

## 2) Comments Received on TIP White Papers

On November 6, 2009, TIP posted for public comment four of its draft white papers on its website. These draft white papers represented the program's consolidated assessment of critical national needs in these areas as well as associated societal challenges that have a scientific or technical solution. These papers incorporated prior TIP research on these critical national need topics, including input received by the time of publication from the NIST laboratories, other agencies, and members of the scientific and technical communities, along with ideas from the many white papers received by TIP. The following four TIP white papers were posted to the TIP website:

**Civil Infrastructure:** *Advanced Sensing Technologies and Advanced Repair Materials for the Infrastructure: Water Systems, Dams, Levees, Bridges, Roads, and Highways*

**Energy:** *Technologies to Enable a Smart Grid*

**Healthcare:** *Advanced Technologies for Proteomics, Data Integration and Analysis, and Biomanufacturing for Personalized Medicine*

**Manufacturing:** *Accelerating the Incorporation of Materials Advances into Manufacturing Processes*

On October 29, 2010, TIP posted on its website six new draft white papers for public comment[5]. The six papers are in the following critical national need areas:

**Civil Infrastructure:** *Advanced Sensing Technologies and Advanced Repair Materials for Infrastructure: Water Systems, Dams, Levees, Bridges, Roads, and Highways*

**Energy:** *Technologies to Enable a Smart Grid*

**Healthcare:** *Advanced Technologies for Proteomics, Data Integration and Analysis and Biomanufacturing for Personalized Medicine*

**Manufacturing:** *Advanced Robotics and Intelligent Automation*

**Manufacturing:** *Manufacturing and Biomanufacturing: Materials Advances and Critical Processes*

**Water:** *New Technologies for Managing and Ensuring Future Water Availability*

As of September 30, 2011, **TIP** had received 71 comments on these white papers. The breakdown of comments by topic area was as follows: Civil Infrastructure –10, Energy –17, Healthcare –12, Manufacturing –22, Water – 2, Bio-manufacturing – 4, and Robotics - 4.

[5] *Federal Register*, 75, no. 209, Friday, October 29, 2009, p. 66737.

# About the Technology Innovation Program

The Technology Innovation Program (TIP) assists U.S. businesses, institutions of higher education, and other organizations— such as national laboratories and nonprofit research institutes—to support, promote and accelerate innovation in the United States through high-risk, high-reward research in areas of critical national need. TIP aims to speed the development of high-risk, transformative research targeted to key societal challenges that are not being addressed elsewhere. Program funds support research that has scientific and technical merit, as well as strong potential for advancing the state of the art and contributing to the U.S. science and technology knowledge base.

TIP was created on August 9, 2007, through the America COMPETES Act (P.L. 110-69), a comprehensive strategy to keep the United States the most innovative nation in the world by strengthening scientific education and research, improving technological enterprise, attracting the world's best and brightest workers, and providing 21st century job training. TIP is part of the National Institute of Standards and Technology (NIST) in Gaithersburg, Md.

- TIP has a novel purpose. TIP has the agility to make targeted investments that are within NIST's areas of technical competence and are not possible by other mission-oriented agencies or programs.
- TIP supports rich teaming. Projects may be proposed by individual for-profit companies or by joint ventures that may include for-profit companies, institutions of higher education, national laboratories, or nonprofit research institutes, so long as the lead partner is either a small or medium-sized business or an institution of higher education. Large businesses may participate in a TIP-funded project, but they may not receive TIP funding.
- TIP is a public-private partnership. TIP makes cost-shared awards of up to 50 percent of total project costs. TIP may award a total of $3 million in direct costs over 3 years for a single-company project or up to $9 million over 5 years for a joint venture.
- TIP complements—but does not duplicate—existing R&D efforts. TIP funds R&D that is not already being addressed, for which other funding (public or private) is not available, and for which government support is justified.
- TIP awards funding in response to publicly announced competitions. All proposals are subject to peer review.

## Contact TIP for further information:

- On the internet: http://www.nist.gov/tip
- By e-mail: tip@nist.gov
- By phone: 1-888-TIP-NIST (1-888-847-6478)
- By writing: Technology Innovation Program, National Institute of Standards and Technology, 100 Bureau Drive, Mail Stop 4701, Gaithersburg, MD 20899-4701

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